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Real estate portfolio analysis under conditions of non-normality: The case of NCREIF

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Abstract (Article Summary)

Modern portfolio theory (MPT) has increasingly been applied in the area of real estate analysis in order to examine and justify the place of real estate in the mixed-asset portfolio. However, the application of MPT presents a number of theoretical problems when the data exhibits non-normality. A study outlines these difficulties, and presents a portfolio selection model based on the Mean Absolute Deviation (MAD). This method can address the problems and produces results that are essentially identical to those produced by MPT. The MAD method is demonstrated and applied to the NCREIF regional data over the period from the first quarter of 1983 to the 4th quarter of 1994.

Full Text (4212 words)

[Headnote]

Executive Summary. Modern portfolio theory, (MPT) has increasingly been applied in the area of real estate analysis in order to examine and justify the place of real estate in the mixed-asset portfolio. However the application of MPT presents a number of theoretical problems when the data exhibits non-normality. This study outlines these difficulties, and presents a portfolio selection model based on the Mean Absolute Deviation (MAD). This method can address the problems and produces results that are essentially identical to those produced by MPT This study demonstrates the MAD method, and applies it to the NCREIF regional data over the period from 1Q1983 to 4Q1994.

INTRODUCTION

Portfolio theory has been widely applied to situations involving real estate in two main areas: first, to examine and attempt to justify the place of real estate in the institutional mixed-asset portfolio (MacGregor and Nanthakumaran, 1992; Byrne and Lee, 1995; Baring, Houston and Saunders, 1995; Pagliari, Webb and Del Casino, 1995); secondly, to investigate the benefits of property type and/or regional diversification within the real estate portfolio (Mueller and Laposa, 1995; Eichholtz, Hoesli, MacGregor, and Nanthakumaran, 1995). Such studies are based on the work of Markowitz (1952, 1959), now often called Modern Portfolio Theory (MPT). MPT postulates that rational investors should select the portfolio of assets from the set of all possible portfolios that offers the lowest level of risk (as measured by variance) for varying levels of return. The set was called the efficient frontier by Markowitz and the goal of the so-called mean-variance analysis is to derive this efficient set.

Although it is in many ways attractive, the Markowitz approach has a number of theoretical problems, and also presents practical difficulties when it is applied to large-scale problems, especially in real estate. First, the utility foundation of the Markowitz portfolio approach has been shown to possess serious limitations which make it incapable of describing the behaviour of a large group of investors (Levy and Sarnat, 1994). Second, the assumption of normality of returns is invalid for most securities including real estate (Young and Graff, 1995). At the practical level, that is for realistically sized asset sets, the implementation of the Markowitz full covariance model has always presented difficulties associated with the need to solve a quadratic programming problem with a large dense covariance matrix. This is compounded in real estate problems because the number of assets is usually greater than the available time series data, and this makes the Markowitz meanvariance approach difficult to apply correctly to actual real estate portfolios.

As an alternative, Konno (1989) has proposed a portfolio selection model based on the mean absolute deviation (MAD) of returns. Konno and Yamazaki (1991) have demonstrated that this approach offers several inviting properties by comparison with the Markowitz approach.

The aim of this study is to outline the theoretical and practical difficulties of using the Markowitz approach, especially for large-scale real estate portfolios, and how the method of Konno can address all of these problems, while producing results that are almost identical to those of the full covariance solution of Markowitz.

MODERN PORTFOLIO THEORY

There are two conditions (each sufficient but not necessary; see Tsiang, 1972), that enable an investor to choose a portfolio only on the basis of its expected return and variance. First, it can be shown that if investors behave as if they have a quadratic utility function, then they will choose among alternative portfolios on the basis of mean and variance (see, for example, Jean, 1970). Second, if the returns are normally distributed, then portfolios can be completely described by two parameters-the mean and variance. As shown below, both of these theoretical conditions do not hold, but even if they were shown

to apply, there are still practical difficulties with MPT in largescale problems.

Utility Foundations

Portfolio selection involves choices among alternatives, where choice is determined by maximization of the expected value of the investor's utility function. In the real world investors' utility functions may be highly complex or of irregular forms. Markowitz based almost all his analyses for efficient portfolio selection on the mean and variance, using the quadratic utility function and arguing that it approximates well enough many other (concave) functional forms. Most theoretical discussions of choice under risk have restricted the analysis to relatively simply functions, such as quadratic utility, in order to make the description and testing of hypotheses more manageable.

The quadratic utility function is, however, subject to serious limitations, which make it incapable of describing the actual behaviour of investors. First it is necessary, when using any second-order function, to bound the range of possible outcomes, since any quadratic function only exhibits positive marginal utility in a bounded range, beyond which it may not represent rational behaviour (Wippern, 1971). Second, the degree of risk-aversion implied by the utility function is everywhere increasing, although empirical observation, as well as theoretical considerations, would suggest decreasing (absolute) risk-aversion (see, for example, Pratt, 1964; Arrow, 1965). The quadratic utility basis for Markowitz MPT has been sustained in the literature essentially as a mathematical convenience, but with most authors recognising the limitations of the function (Sarnat, 1974).

Normality

Without the condition of quadratic utility, the theoretical justification for the Markowitz approach rests heavily on the assumption of normality of returns. In the early 1960s however, Mandelbrot (1963) suggested that the distribution of security returns might be "fat tailed," that is having more outliers than would be expected from a normal distribution. The empirical work of Fama (1965) confirmed this hypothesis, restricting attention to the class of stable paretian distributions with a characteristic exponent a between 1.7 and 1.9 as opposed to 2.0 for the normal distribution. Under such conditions the sample variance (or standard deviation) is undefined.

The normality of real estate returns has also been questioned by a number of studies. The first, by Ward (1979), investigating the returns of U.K. property bonds, found that the cumulative distribution lacked small negative returns, showed excess large negative returns and an overabundance of small positive returns in comparison with the cumulative normal distribution. Ward attributed this to the use of appraisals in calculating capital returns.

In the U.S., Miles and McCue (1984) and Hartzell, Hekman and Miles (1986) found that the returns of several indices did not appear to be normal based on skewness and kurtosis statistics. This was supported by Brown (1985) in a U.K. study of 135 individual properties using monthly data over the period from January 1979 to December 1982. Liu (1988) investigated the nominal and real returns of several real estate indices. His conclusions were that nominal returns exhibited non-normality, although no evidence of non-normality was found for real returns of quarterly data from the second quarter 1978 to the third quarter 1986.

Myer and Webb (1990) and Young and Graff (1995) returned to the approach of Fama (1965) to find the characteristic exponents that best describe real estate returns for both indices and individual properties. Their results corroborate the findings of Fama that returns could best be categorised by a stable infinite variance skewed distribution with the characteristic exponent of approximately 1.5 during

virtually all sample subperiods and across all real estate types.

The argument therefore is that if stable paretian distributions are the appropriate measure of real estate returns, then the use of variance as a proxy for risk is unrealistic.

The Mean Absolute Deviation (MAD)

The findings of Fama (1965) for securities led him to advocate the mean absolute deviation (MAD) as an alternative, indeed preferred, measure of dispersion (risk). The MAD has the desirable property of giving less weight to outliers than does the standard deviation. The MAD also displayed a high degree of substitutability with the standard deviation for the purposes of assessing the riskiness of **assets**, according to Cooley, Roenfeldt and Modani (1977) who used **clustering techniques** to test the interdependence of fourteen risk surrogates suggested in the literature. The MAD is also a stable risk surrogate according to Modani, Cooley and Roenfeldt (1983). The ex post MAD therefore provides a useful ex ante evaluation of risk, especially as portfolio size increases, irrespective of the time horizon.

The MAD has also been given official status as a recommended measure of dispersion by the Bank Administration Institute (1968). The findings of Young and Graff (1995) and Myer and Webb (1990) would seem to imply a similar endorsement for the MAD as a measure of dispersion for real estate returns that would prove analytically beneficial.

Practical Problems

Even if the theoretical foundations of the Markowitz approach did hold there have always been practical difficulties with implementing a realistic large-scale full covariance solution. In the main these problems revolve around the need to manipulate a large dense covariance matrix. The model requires m(m-1)/2 covariance elements, where m is the number of assets.

For a realistic problem with hundreds of securities this requires thousands of calculations. The problem is further compounded since most, if not all, of the elements of the covariance matrix are non-zero, making the quadratic programming solution very difficult if m is large, say, greater than around 500.

Both of these problems led to the development of simplifications of the programming problem through the use of index models (Sharpe 1963; Perold 1984) to reduce the off diagonal elements to zero, leading to a reduction in the number of calculations to 3m+2. This also turned the "not so easy" quadratic programming problem into an easier linear programme, that offered advantages because of computational simplicity, speed and the wide availability of computer programming packages that could handle thousands of assets and constraints.

Accumulated evidence, however, suggests that the single index model approach is misspecified. Bernard (1987) for example provides evidence of significant intra-industry cross-sectional correlations in contemporaneous market model residuals. This implies that the correlation of assets with a common index will not capture the total covariance amongst those returns. A further problem relates to the choice of index used to represent the market (Bajtelsmit and Worzala, 1995).

There is an additional consideration that is especially relevant to disaggregated real estate data. This is the problem of the large number of asset classes (m) relative to the small time series of data (T) that are needed to estimate the sample variance-covariance terms when using historic data. If m is greater than T, the covariance matrix would be singular, and cannot be inverted. On the usual assumption that short sales are not allowed, the problem can be set up as a parametric mathematical programme, but this still

needs m to be less than or equal to T. Otherwise it is possible to form risk-less portfolios from a set of what may be very risky assets (Markowitz and Perold, 1981). In a more practical sense, research by Giliberto (1990), Graff and Cashdan (1990), Wheaton and Torto (1990) and Gyourko and Keim (1992) suggests that in real estate investment analysis, the use of annual data is preferred to quarterly or monthly because of inconsistencies, lags and seasonality in the appraisal-based data. Using annual disaggregated data limits the data set to very few observations in both the U.S. and the U.K., with m certainly greater than T.

All this suggests that a portfolio optimisation process that does not require estimation of the covariance matrix, which uses the MAD as its risk surrogate and has a linear programming solution would prove extremely beneficial to portfolio analysis involving real estate. Konno (1989) provides such a solution that Konno and Yamazaki (1991) showed can produce results that are a viable alternative to the quadratic programming approach of Markowitz, especially for large-scale problems. The formulation of the portfolio selection problem (equation 16 in the Appendix) has a number of useful properties (Konno and Yamazaki, 1991).

A linear programme is much easier to solve than the parametric quadratic programming formulation of Markowitz.

There is no need to calculate the covariance matrix to set up the model. This has two advantages: first, computer storage is saved and second, the difficulties of handling a covariance matrix in which m > T are avoided.

An optimal-weight vector contains at most 2T+2 positive components (Danzig, 1963) which remain constant regardless of the number of assets. This means that very large-scale problems with thousands of assets can be solved in real time. It also means that T can be used, if necessary, to restrict the number of assets in the optimal portfolio.

A COMPARISON OF MAD AND MARKOWITZ (MPT)

In this section the performance of the MAD linear programming model is compared with the MPT full covariance approach of Markowitz using total return data for property types/regions of the U.S. NCREIF Index. The comparison is made using forty-six quarterly observations (T) of sixteen property types/regions (m) over the period from March 1983 to June 1994, thus ensuring that m is less than T. No constraints, other than those defined earlier, are imposed.

To compare the efficient frontier produced by MPT with that from the MAD, the following approach was adopted. The maximum return and the minimum risk portfolios were obtained using MPT. A number of intermediate portfolios along the frontier were then derived by dividing the difference between the max. and min. returns into equal parts. These returns then became targets (R*) at which portfolio risk was minimised. The MAD efficient frontier was generated by adopting a slightly different approach. The maximum return and the minimum MAD portfolios were found, but the intermediate portfolios were derived using the same target rates-of-return as for the MPT case. The portfolio weights obtained in MAD space were then used to calculate a portfolio standard deviation in MPT space for comparison purposes. The analysis in MAD space was made using both formulations of the MAD programming problem in order to check the equivalence of the approaches. Results (available from the authors) show that the outcomes are identical, but that solutions by the linear method are reached many times faster than from the general formulation. Since the linear programming solution would be preferred in largescale portfolio applications, the results presented here and below are from the linear model.

Exhibit 1 shows the descriptive statistics for the sixteen property types/regions. It is apparent from the Jarque-Bera test and the skewness and kurtosis statistics that the majority of the series are not normally distributed. Given the arguments above, the application of MPT might well therefore be considered inappropriate, except for the purposes of comparison.

Exhibit 2 shows the frontiers generated by the MAD. That is, the efficient frontier in MAD space was calculated as above, and the resultant portfolio weights were used to calculate a portfolio standard deviation. The MAD frontier is quite smooth by comparison with the standard deviation frontier. The irregularities of the standard deviation frontier are a consequence of using the weights produced by the MAD solution. A noticeable feature of the standard deviation frontier is the inefficiency of the final portfolio calculated from the efficient minimum MAD portfolio. The implication of this is that there is an efficient portfolio in standard deviation space which has a higher return for the same level of risk. Exhibit 3 presents the efficient frontier generated by the full covariance model of Markowitz and the standard deviation frontier produced by MAD which is shown in Exhibit 2. For a good deal of the frontiers' lengths, the two coincide. This would imply that the assets in the efficient portfolios are the same, although their weights are likely to be different for at least some of the portfolios. The means, standard deviations and the weights of the assets in the efficient portfolios are shown in Exhibit 4. This confirms the minimal differences in portfolio asset composition resulting from the two approaches and the changes in asset weights that occur at the lower end of the frontiers. Given the sector returns, with Retail offering such superior performance in three of the four regions, the assets selected by both approaches are not unsurprising. For this example, regions, rather than sectors, offer greater diversification benefits.

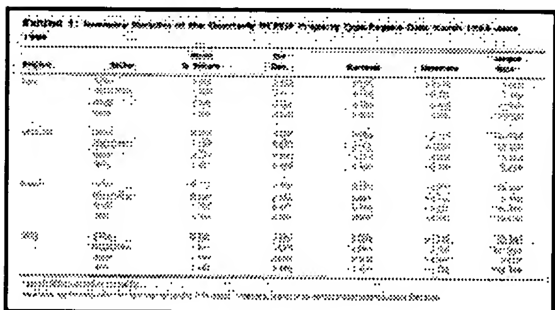

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Exhibit 1:

It will also be readily appreciated from Exhibit 4 that the difference between the standard deviations produced by the MPT and MAD models is very small, at most only 0.068%. This implies that the quarterly data, although non-normal, contains only a few outliers and inspection of the original series shows this to be the case. In other situations where this might not be the case, the two frontiers may diverge to a much greater extent.

APPLYING MAD

As suggested above, a number of authors have argued that annual data are superior to either quarterly or semiannual data for investment analysis. If this is so, only eleven years of NCRIEF total return property type/regional data would be available from the set used above, from 1983 to 1993. This means that m becomes greater than T, and this precludes the application of MPT in the investigation of the benefits of property type/ regional diversification using the NCREIF series. Indeed, this has forced the use of quarterly or halfyearly data for all such work, irrespective of the data series used.

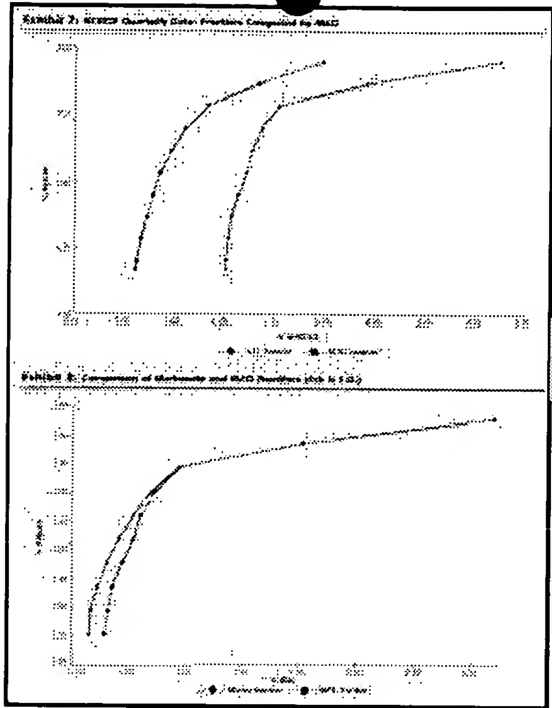

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Exhibit 2:
Exhibit 3:

The fact that m is greater than T is not a problem if the MAD approach is adopted. The MAD approach therefore offers the opportunity to use annual data with the confidence that the results obtained will not be very different to those produced by MPT.

Applying the MAD linear programming method to the annual property type/regional NCREIF data produces the MAD frontier shown in Exhibit 5. Although it is possible to generate an equivalent set of "Portfolio" standard deviations using the weights produced by the MAD linear program, the need to use a statistically suspect covariance matrix to do this makes unreliable results very likely.

Exhibit 6 shows the asset proportions, means and MADs produced by the MAD programming approach. The close similarity between the assets selected by the MAD using annual data and those produced earlier using quarterly data in both MAD and MPT space is not unsurprising. The asset weights in the annual and quarterly cases are different, as is to be expected, and of course they should not be compared except in the most general way. It may be, however, that the results from studies using quarterly data are a reasonable reflection of those that would be produced by using MPT on an annual series of sufficient length.

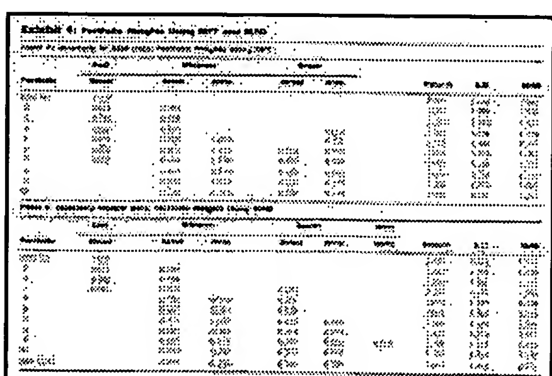

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Exhibit 4:

CONCLUSIONS

This study has shown that the application of MPT to problems with large numbers of assets is subject to a series of theoretical and practical limitations. By using the MAD as the measure of risk, and a linear programming method for the derivation of efficient portfolios, all of these difficulties can be surmounted. In a comparison of the full covariance method of MPT with that of the MAD linear programming approach, it has been shown that both solutions select the same assets with only minor variations in portfolio weights. This leads to efficient frontiers in standard deviation space that are effectively identical. The MAD method was then applied to a case using annual data, where m is greater than T, and when the use of MPT would be suspect on statistical grounds. The solution obtained in this case proves to be broadly similar to that from the use of quarterly data, and hence is probably a reasonable reflection of the results that might be obtained if MPT could be used.

This is not to say that MPT can no longer be applied. Rather, its application should be restricted to those cases where the number of assets is smaller than the number of time periods, as in the strategic allocation problem. MPT may also continue to be used by those investors who still, because of its familiarity, prefer the standard deviation as their measure of risk. The MPT approach also offers a somewhat richer analysis. In small asset-sized problems, the reasons for asset inclusion or exclusion from the efficient portfolios can be rationlised by inspection of the correlation matrix. For larger data sets, with m greater than 20 perhaps, inspection of the matrix becomes impractical.

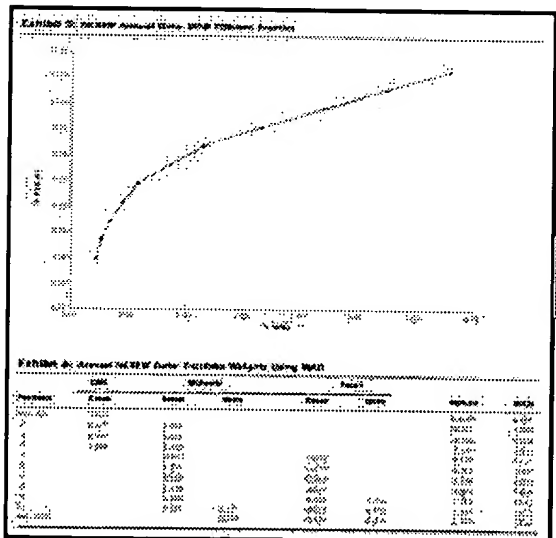

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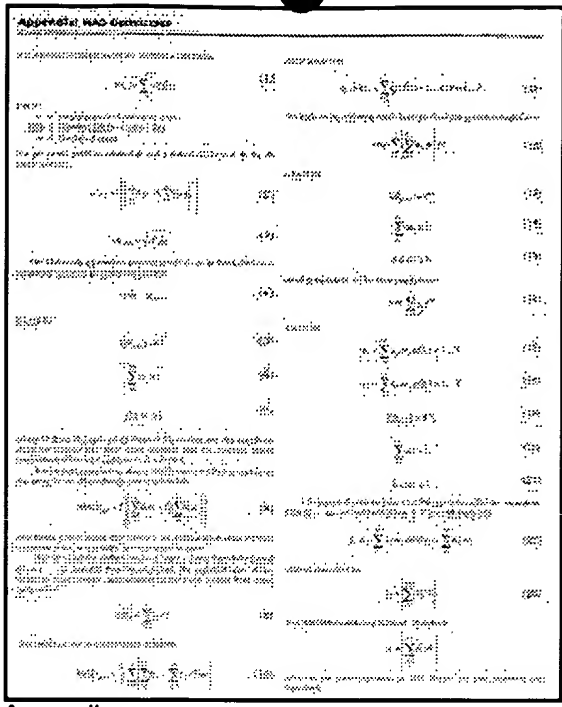
Exhibit 5:

Exhibit 6:

The simplicity, speed and ability of the MAD linear programming approach to bypass the covariance matrix makes it an especially attractive alternative to MPT for real estate portfolio analysis. As has been shown, the MAD approach will produce results, which when converted into standard deviation space, are identical to the MPT solution in situations where this is possible. It offers the potential of exploring diversification possibilities in cases where MPT is not applicable.



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